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PUERTO RICO NUCLEAR CENTER

RADIONUCLIDE CONTENT OF SOILS FROM BARRIO ISLOTE,

?ARECIBO, PUERTO RICO

(JUNE 1976)

By

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and

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On the use of Appendix A for inferences

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Chapter 1

A, Introduction

?The radioisotope content of soll and vegetation samples in .

Puerto Rico on clearly defined transects was first measured by Kline (2968) and Kiine et. a1. (1973). ?The accent of these studies vas on ?the determination of radionielide residuals vhich bad fallen out or rained out on the Leland after the explosion of fission devices in the atmosphere. Anong the hypotheses examined vas the relationship Detween rainfall and radiomelie content (Odun et. 9241970) and a test of a hypothesis similar to the proposed "continental eftect? (Roser fand Cullen, 1965; Meyer et. el., 1968). Te following radionuclides, with the half-tives (72/2) listed, were found in aost samples: Ce-24i/ Proulil, T 1/2: 264 aays/T 2/2: 17.3 minutes; n-sk, T 1/2: 303 anys; C8-237/Ba-137 =, 72/2: 30.2 youre/T 1/2: 2.55 min.; and, rarely, tr-9580-98, T 1/2 65 days; T 1/2: 35 days (Definition of chentoal eysbole 12 given in Appendix B)

In Wovenber, 1973, the Terrestrial Eeology Program of the Puerto Rico Wuciear Center began a series of surveys in Barrio Telote, Arecibo, Puerto Rico. The objectives of these surveys were the develoynent of seotions of an enviromental report of that area for the Puerto Rico Water Resources Authority. The entire report was used to comply with federa. veguletions governing the construction and operation of themmo-?mclear pover generation facilities in the area. Some of the surveys vere connected with the collection of backeround, radiological aata

such as the normal background levels of gama activity (Block et. al.

a

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1975) and the identification of radiomclides already present in the proposed exclusion zone.

Interstingly, Kline (1968) and Kine

2. (2973) ?o not appear to have studied soil radioactivity attributable to primordial radiomiclides, even though it is estimated that 97% of natural environmental background radioactivity to which man La contimiously exposed

40 attributebie to exteston by primordial terrestrial rediomelides (Ksxty, 1974) and comte rays, Sone radiomclides produced during atmospheric testing of fission or fusion devices can, however, easily enter the food chain 2eading to Incorporation in the tuman body and their importance cannot be mininized.

The cessation of atnospheric testing of strategic mclear devices by the most technoligteally advanced nations (1.e. U.S.A. and ?U.S.S.R.) began with agreements in 1958, and continue by virtue of a ?treaty negotiated in 1963. This has led to @ decline in environmental

Jevels of sone radionuclides, with T 1/2 less than

years; some of

which had been produced on a large seale since 1945. Nations vhich have developed miclear arms capabilities more recently such as France, People's Republic of China and India have concentrated, for the most part, on small ?but relatively high yield devices, Most of these devices are generally believed not to have been of the megaton class and have probably not produced copious quantities of Pu-239.

?The purpose of this report ie to present and interpret gamma ray energy spectra measured on soil samples collected in the projected ther-

nonuclear pover plant exclusion sone in Barrio Islote, The interpretation

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consists of 2 chapters, in the first of vich an identification of peak gama energies with specific rediomclides will be made. The second chapter 1s devoted to estimating the soil burden of Cs-137 in Barrio Telote as a complement to estimates made by Kiine (1968) and KLine st al, (2973). In addition, a Caveat Lector has been added for the Purposes of cautioning the user of the data contained in Appendix A,

concerning their inapplicability to petrology of the zone.

B. Qualitative Survey

1, Experimental Design

Sone 19 samples of soil were collected at points on 3 tran=

sects within the area designated as the exclusion zone by the FRWRA. ?The

?area {s show in Map T and relates the position of the exclusion zone to

coustal features of Puerto Rico and to other tome on the island. ?The

zone 48 marked as "FROFOSED NORCO SITE",

?The transects were marked out from north to south through

the eastern, central and western sections of the zone. The zone 18 nome

snally bounded by the 66°37"22"and 66°36'30" weet longitudes and the

transects were nominally bounded ty the 1629'36" and 18°29'6" north

Jatitudes. The proposed plant site has co-ordinates of approxinately

66°36'57" west by 18°29'6" north. A11 samples were collected vithin

essentially 1 im, of the proposed plant site.

?The samples collected were all taken from surface 6 inches,

The sotis of the

site are the products of weathering of calcareous

sandstones with the exception of the sugar cane Meld sotis most of

which are organic soits (Bonnet and Roberts, 1967). owing to the close

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proximity of the zone to the coast, these solis are probably salty and

?would be expected to contain radiomclides from the decay of Ra-226,

Gama spectra of the samples vere taken using e lithium

drifted germanium detector (Gelt) with a nominal efficiency of 1%

operated at liquid nitrogen temperature. ?Typical couting tine wae

2000 mimstes and a 095 channel anslyzer was used to store the pulse

height information. The energy increment of the multi-channel anslyzer

was 1/2 KeV per channel using as an energy calibration peak the second

petk of the Co-60 doublet at 1,332.51 KeV (Dyer and Bate, 1972). ALL

soll samples were air dried and mechanically eruched before mounting over the detector ina Marinelli beaker of polystyrene construction.

2. Results and Discussion

8. General,

?Actual data on counts versus channel musber, the approximate Jocation at which samples were collected, and @ description of gro properties of each sample are given in Appendix A. All samples exhibited nearly the same pattern of peaks and the richest spectra were cbserved for samples designated ABBHDO3, ABOOI6 and ABSCF2, vnich were clay, sandy ?Lown and sandy mick (Tiburones Muck; 0.f. Bonnet and Roberts, 1967) respectively. Since the spectrun of ABBIDO3 was not only the most Antense, but also the richest of all of the spectra, a plot was ade of the Jog of the musber of counts in @ channel vertus the energy of channel to show clearly how the well-resolved spectrum appears. This

plot 4s shown in Pigs. I-VI.

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, Primordial Radtomelides

Peak assignments are based on the tactt assumption that

the majority of the radionuclides encountered are primordial in :

origin or are descendants of primordial redtomiclides (Kanasevich, 1968).

?The uranium (in+2) and thorius (In) decay achenes (ete. series] shown in

Figs. VII axl VIIZ, respectively are principally responsible for natural

radioactivity, although K-l0 48 also a very taportant source of natural

?enviromental gama ray enaissions. The energy of the gama ray enitted

?by K-l0 is relatively high (1460 KeV); it is relatively abundant radio-

melide (0.01196 of all natural potassium 1s K-H0); and 4 is a strong

enitter (approxinately 12.36 of all K-NO aisintegrations results in the

emission of a gamma ray (Leighton, 1959)). The fact that potassium 1s

© meromtrient, essential for grovth and reproduction of all animals

and plants, establishes K-10 as prine candidate for gama ray induced

mutagenicity. Snall inputs to natural enviromental radioactivity also

come from the neptunium (lin+l) series (Fig. IX) and the actinium (lint3)

series (Fig. X). The parent meclides of the thoriu, uranium, neptunfum

and actinium series are Th-232, U-238, p-237 and U-235, respectively

?and the half-lives for each parent are 1.39 x 102°, 4.51 x 109, 2.05 x

wo, and 7.07 x w years respectively. The average isotopic ratio of

1-236 to U-235 eatablished for many different samples taken from the '

natural enviroment is about 138.5: (Letghton, 1958), suggesting that

gemma radiation from U-238 decay products is probably mch more readily

observable than Is gamma radiation from U-235 daughters (Bete, 1975).

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FIG VII

(4n+2)

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FIG VIII

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FIG IX

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FIG X

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(ane3)

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Crustal abundance of each of the primordial parent compounds
Tas been estimated by Taylor (1964), ant shove, as might be expected from
its mich shorter half life, thet there is « negligtble quantity of lp-237
in the crust, Average crustal concentrations of 9.6, 2.7 and 0.019 ppm
for i232, U-238 and U-235 respectively vere reported (Taylor, 1964).
This suggests that Th-252 and ite more recent daughters are probably
easter to observe than U-238, though the older daughters of U-238 vate
fire gama enitters might be observed using the Ge-Li if long counting
times are used. The protebility of cbserving a gama ray fron U-235 oF
its progeny is probably lov unless chenteal or physical pre-concentration
of uranium in the sample is carried out.

The energy dependence of the efficiency of the Ge-Li detect
or As a particularly frustrating weakness when assays of gauma-enit-

?ing radiomicliges are attempted. The drop-off in photo peak detection efficiency as the enerey of the peak increases from 50 to 2000 Ke ts rather variable and, in general, 1s non-linear nominally between 50 and 2000KeV (Gordon et. al., 1968). Indeed, for two Ce-Li detectors studied, shoto petk efficiencies for 2000 XeV peaks were approximately 1/30 and 1/250 their respective values for the 50 He? region (Gordon et. al.,2%68).

The data also suggest thet st higher energies (1.

+ 500 = 2000 Kev),

rather long counting times and background substraction or count rejection ?techniques ought to be applied. The first of these alternatives was used during some quantitative work and counting times of 2000 mimstes were the Jongest: practical counting periods. These counting tines are long enough

?to develop sufficiently objective peaks for daughters of primordial radio-

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nuclides vbich entt guma rays wth energies in excess of 500 KeV, and Which are expected to be present in the samples,

Referring to Figs. I-VI, beacon eneray peaks for Ra-226

correspond quite closely to Literature values (Dyer and Bate, 1972;

Delepov and Peker, 1961) in fact the energies are sways within 3/2

= 1 Ke of the Literature valu

The following primordial radionuclide

Amughters are represented by energy peaks in the gemma spectra and are

also attributed to the (Im2) series: The23h (T/2

245 days), Po-20h

(T 1/2 = 26.8 mimtes), Bi-2i4 (T 1/2 = 29.7 minutes) and 71-210

(T 1/2 = 1.32 mimites). The inferred abeence of series mesbers Pa-23h/

Pa-o3h m (T 1/2 = 6.75 hours/T 2/2 = 1.27 m), U-234 (T1/2 = 2.3380"

years) and Th-230 (Ti/e = 8.3x10" years) is explained as follows.

Pa-23 and Pa23' m are both the sine radiomelide, the lower

case "a" indicating an excited melear eneray state

jocimted with the

radiomclide. The (ln+2) decay seri

© shown tn Fig. VET indicates that

M234 1s formed upon CL ~enteston of U-258, The TH-23 ambaequentiy decays vie, B- exiasion to Pa-23h n, the excited rediomclide. ?The Pac 23h m can then either decay to the ground state, creating Pa-23h through an internal transition (IT) or it may decay directly to U-234 via

BB = entssion. the atrect decay to U-034 ts most frequently cbserveds 99.87% of all of its disintegrations result in U-23l. However, the efficiency of eatsston associated with gama energies shove 43.5 Kel ts 60 sail as to mike thece resonances uncbuervable tn the experinental arangenente used. The Pa-dSl formed trom 0.136 of the Pag3im via on TZ decay can also produce U-234 via a 6 ? emission.

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but the quantity of Pa-23l 4s so saall, that possible visible re-

Sonances are cbscured by background and chemical separation of this

Asotope would be necessary for tts spectrum to be visible using the

experimental configuration employed in this vork.

?A gama energy resonance at 53.3 KeV attributable to
U-234 probably is obscured due to metallic shielding used over the
Ge-Li detector and Limiting its detection to all but the most intense
peaks near this energy. Another peak vhich could be attributed to
U-234 at an energy of 120.9 KeV is not considered to be statistically
reliable and was (subjectively) eliminated.

Elenent ?-230 lacks intense gamma pesk enission st any
energy. Relationales similar to these apply to the apparent sbsence
of gamma emission peaks due to Rn-222, Po-218, and Po-2Il, The ground
state of B-210 docs not emit observable ganna rays and Fb-210 docs
not exhibit strong gamma resonances in the region between 50 ani 2000
KeV. As indicated in the decay scheme of Pig. VII, 11-206 1s formed
4m such snail quantities with euch @ short half fe that it te un
Likely that any peaks attributable to it would be distinguishable
from background.

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Flement At-218 is not an enitter of gama rays and 4e formed
in only small quantities which decay rather rapidly. There are gama
Fesonances which correspond to T2210 and the guma peak at 795 Kev
is quite intense (Lederer et. al., 1967). Nevertheless, 71-210 i

formed by only .O\f of the distntegrations of Bt-214, and positive identification does not seen varranted on this basis. Moreover, Tl-

220 vith @ relatively short half ite does not build up and the peak Ssstgrment made for 71-210 mst be considered tentative.

The daughters of Th-232 (the hn series) are clearly present, although an overlap of energies with members of the (lint) series obecure some quantitative aspects of the analysis. The following Th-232 positive Adentifications were made: Th-252, Ae-228, Ra-00l, Tb-222, BL-212 and 72-208, Element Ra-228 has no intense gamma peak in the range of energies considered. There is a very slight indication of a peak at 542 Ke¥, indicative of Rn-220,but the subjectively dram figure does not show this clearly, and Rn-220 being a gas with T 1/2 = 55 seconds may not show up sharply prior to chenteal concentration of ite precursor Ra-22h. Also, only .O%f of the disintegrations of Rn-200 result in gam-Ba ray exissiont. The two radionuclides Po-216 and At-216 do not emit gamma rays upon disintegration, The radiomelide Po-?ie(T 1/2 « NS seconds) is formed by « sali percentages of B? ehissions from Bi-222, the majority of the Bi-12 emissions leading to Fo-2i2 (T 1/2 « ?~ +03 microseconds). Thus while Po-212 dose enit a gam ray of

energy near 570 KeV, it is not observed.

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c. Radionuclides Created by Fission and Fusion Devices

Aside from sone transuraniun elements, (1.¢. Pu-239, Ame
2h ete.) fission and some fusion devices produce few radionuclides
having 1/2 Lives comparable to a generation of mankind. Of these few, a
sunll percentage are considered particularly important because of their
?tendency tovard accumation in bicta and "biological axplification?.
?Among these elenents Cs-137 (T 1/2 = 30 years), Ce-thl (T 1/2 =
284.4 days), 8b-125 (T 2/2 = 2.73 years), Sx/¥ - 90 (T 1/2 = 28.9
years/64 hours) and others of comparable 2/2-1ife are considered suf-
ficiently important thet complete monitoring capability for them 1s
4 requisite for construction and operation of thermonuclear pover
generation factiities.

Constant ratios of K to Cs in biota (Fisenbud, 1963), the
tendency for mamuls to concentrate Sr-90 in bone and cartilage tissue
(Rand Corp., 1953) and the deleterious effects of 1-131 binding to thy-
roid gland are thus recognized in legal requirenents for pre-operational,
monitoring prograns for miclear power generation facilities (Puerto Rico
Water Resources Authority, 197ha).

Wine (2968) and KLine et. al. (1973) reported on radio-
miclides measured at @ time when the USAAUSSR atmospheric test-ban
treaty had been in effect for about M5 years. They found the fission-
produced radionuclides ost easily determined using NaI (T1) detection

fas mentioned in the Introduction. The inspection of the gama spectra in Appendix A ty us revealed that Cs-137, which Le produced in high yield ty both fast and siow neutron source devices, both by U-235 and Pu-239

3.

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Tesion, is noticeably present in all of the soll samples taken (Gnergy = 661.6 Kev).

Radiomiclides which also are suspect are Sb-125 and Ce/Pr-sh netther of which can beastablished ac present on a statistically Feliable basis by the peaks corresponding to energies of gama rays emitted by thes. This identification for these two fiselon-fusion Profuced radionuclides 1s considered tentative. In the case of Sb-225, with T 1/2 = 2.7 years, many cama rays are enitted upon aisin-?tegration, of which the most intense occur at energies of 427 and 598 Ke respectively. ?The case for Ce/Pr ie veaker both because of ite shorter half-life and the lack of prominence of either of the peaks ascribed to it (133.5 KeV and 80 Kev). ?The data do suggest vat should be a prominent Pr-1llh peak at 697 KeV, but the peak lacks suffictent Gefinition. The 80 KeV peak from the Ce radioisotope is considersbly

?roadened by other, low energy peaks, one of which may be due to low feneray resonance suns from heavier transuranie elenents.

Element, Pun239 is tightly bound by sofl, showing little propensity for transfer into plants or animals and it is not easily Antroduce into the food chain (Bisenbud, 1963). There is no reason for suspecting {ts presence in ABEHDO3 or other samples however, since it ds not easily detectable even with higher efficiency Nat (72) equipment (Burson, 197). The 129 KeV peak is interesting in that it is rather broad, implying that more than one radioitotope is contribut= ing to its intensity. Furthermore, ?t 4s clearly sveent from the back-

Ground spectrum. Further work including chemical separation and re-

othe

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counting should be used to establich whet constituents are present in this peak and if any measureable level of Pu-239 42 present eince Pu-239 may de a future source of energy in muclear pover plants.

©. Effects on Boology

The fact that the distribution of gamma energies in this ?area is nearly wholly dependent on primordial raaionuclies coupled with the previously measured low background radioactivity (Block et. al.,

1975) would seem to rule out any unusual mutagenic activity attributable to radiomiclides and localized in Barrio Islote. Fallout patterns would Ihave no obvious clinatological mechanics for concentration euch as that postulated and observed by Osburn (1963) and Osawa et. al. (1962).

on the other hand, Osturn (1965) has pointed out thet in cases where a high radioactivity exposure or radiomiclide burden 12 coupled with other environmental stresses during radio-sensitive periods in the Life cycle, some preferential uptake is possible and mitagente activity would be expected to increase. Also, the distribution or geo-graphical range of a species of plant or eninal may be affected ty natural primordial radiomclide distributions.

Anomalous morphological forms have been shomn to be more prevalent in tundra species exposed to higher radiation dosages (Osburn, 1961; Osburn, 1963) and granite outerops have been shown to have com munities in which the distribution of plant species follows the radio-activity gradient in the outerop (MeCommiek and Cotter, 196). Insoluble JInmmig acid or peat fractions in the upper layers of soils has been invoked

85 @ geochemical enrichnent factor for (UO>)'*(Szalay, 1964). Although such

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studies are complicated by the form end solubility of the eation under investigation, Th" ought to be enriched in these fractions at least as well as vo,*,

?The plant census made in the Islote aren has not revealed ?any unusual or marked trents with respect to changes in morphological. form, although plant analysis at the cellular level has not been carried out. Periods of severe extended drought come contiming for as long as 3-4 months might be considered important stress factors in developaent of plant communities particularly on the shallov sandy sofis of the Limestone formitions. Under such conditions, a sudden increase in the natural background radiation level could produce observable changes in ?the morphology and population distribution. Genetic changes also ought

to be accelerated, perhaps to chservable levele within a few year:

Chapter Ir

Cestun - 137 Estinates

One 1000 gm. sot sample, ABBPON for which the gama spec-?trum using the Ge-Li detector had been taken, was subsequently doped with 100 pCi (nominal) of a comercial preparation of the radionuclide, ?The dopant Cs-137 vas purchased from New England Nuclear, Boston Mass.

45 @ 1 mCi sample in approximately 0.5 M hydrochlorie acid solution, with @ listed radiochemical purity of greater than 99%. ?The contaminated soil (ABBIOM Cs) was then counted for the sane period of time as the uncontaminated sample and a background eubstraction was mate.

For thie measurement, a subjective peak integration was

employed. ?The interpretation was based upon the cesium peak charact=

a6.

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eristics demonstrated in Pig. TV, Chapter I. In general, the count maxims ley between tvo channels and in all spectra st an enerey bet ?ween 611 and 613 KeV. ?The integrated peak count included the two central channels and six channels on either eide of these two. Since Cs-137 4s present in the soil at a relatively low level, and the soil matrices ?were sintlar, the Ce-137 spike inorenent was considered sufficiently low that © Linear extrapolation of the inorenent would give @ reasonable cestimute of the original Ce-137 burten. Estimates for other senples were based on the counts per Ca-137 increment in thts sample as well, even though ?there may have been slight variations in the geonetry of the counting configuration.

?The sample with the C5-137 spike - ABBOL + - showed an increase

of 27.3 counts per pCi of Cs-137 over the unepiked samples. Theeror in

this incremental activity 1s estimated to be no worse then about 10f and ?this value was applied to each sample to calculate an activity per gran of sample. The calculated activities are show in Table TI-1.

?Two of the samples: ARMTO2 + and ABOOLI + vere spiked with HC1 to give erhanced K-K0 peaks compared with their unspiked counterparte ABMTOW and ABOOI4 respectively. The KCl used vas of analytical parity and is considered free of Cs-137 contamination, Typical reproductbility of results from long Ge-Li counting can be inferred from ?the fact that the samples not spiked with KCL gave Ce-137 activities of 0.226 and 0.121 pCi/em respectively, while the spiked samples exhibited Cs-137 activities of 0.125 and 0.186 pCi/en suggesting thet a

more righdily standardized method than this one ought to be developed

ait

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unless an assay reproducibility of 35-Hof can be tolerated tn environmental monitoring of gol near a nuclear plant.

?An average Ca-137 activity with a calculated standard

deviation (to show an epproxinate range of variability) was cal-

culated excluding samples ABOOOY and ABBOOWL of which such @ small

quantity respectively vas counted, that it was felt thet a counting

Geometry equivelent to the other samples was probably not conserved.

?This average Cs-137 activity was 0.131 pCS/gn with @ aistrtbution in

values characterized by @ standard deviation of 40.019 pCi/gm. Den-

sity measurements on the undried soil camples vere not taken and

Girect comparison with the data of Kine at. al. (1973) 4e not pos.

sible since that data vas reported in tems of activity per unit

surface area of soil.

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Table TT

Sample AST Activity in y0i/em

asioos our

Assoowi* o.138

ammo

x0001

?aneow

030010

omscre

?ABTS

0026

animes

?m0014

amO12

?83000 8

ABasL

?apooor*

?ABDOF2

-xBBCOL

?RBOOLI,

+8003,

AROS

?Values for these samples are given lover significance because the

weight of sample used indicates that counting geometry may have been significantly

Aicterent from other samples.

+ AMMMOe+ 1s AMMTON with a Imown KC spike

ARCOM is ABOOLI with @ know KOl spike

-19-

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Lector: On the use of Appendix A for inferences of the geclo-

@ical and petrological development in the northern coastal zone of

Puerto Rico.

An area long the north coast extending eastward toward

Dorado has been suggested as a possible petroleum exploration region.

Puerto Rico is situated on the northeastern edge of the Caribbean plate,

?9 reasonably stable seisnic situation vith a major earthquake repett-
tion rate vhich is unknown. ?The last major earthquake associated with
the submersion of the outlying Atlantic sea floor took place before
reconted history and despite some mincr trenors felt occasionally on
?the western and northern part of the island, Puerto Rico mst be con-
sidered a less than ltkely place for the occurrence of a major tremor.

Nevertheless, since the Caribbean plate is fairly well de-
Lineated and diving of the Atlantic sea floor has occurred on its east
ern and northern (the Puerto Rico Trench) edge, there exists a strati-
graphy in vhich petrologists are generally skeptical about the probabi-
lity of encountering major petroleum deposite (Atwater, 1976). However,
?the phystograpty of the northeoast site has been reviewed (Puerto Rico
Water Resources Authority, 1974 b), se an important consideration for
petroleum exploration,

?The Clenaga Tiburones, bounded by ridges of the Arecibo
and Manat{ rivers is filled with approxinately 30 meters of peat and
organic rich clay and ie probably underlain by Limestone deposits
(bfaz, 1973). At least four Quaternary eolianite ridge Lines occur on

the north central coast, and it 1s believed that the entire Eolienite se-

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quence was forned during Pleistocene sea level lowering. Additionally, Shallow reflection seismic data off the north coast near Arecibo indicate ?the presence of at least two alluvial fills, to about 60 meters below sea~ revel.

?The following conclusions ty Hassan (1973) and Hassan and Fossin (1975) suggest that Limestone corings both from land and sea cide should be exanined with respect to the Th/E ratio ss determined using gan- ma spectroscopy, vhen evaluating of}-bearing potential of rock substrate.

Tn sodinentary rocks thorium bas a detrital crigin and renains stable during alteration and subsequent diagenesis. Second, the TH/K ratio and the parenagnetic electronic resonance associated with organic Phases show parallel trends. As mentioned previously, the muse acid or peat-layer mobilization of tonic species such as Th? ought to be at least fas good as Wo," barring widely different solubility Certainly, x sa quite soluble in any aqueous phase and might be expected to be well-fixed

in Inmic layers and retained during subsequent diagenesis. Hassan (1973)

jerto thet Th is almost entirely concentrated in clay fractions end that 1 1s Delieved to renain stable during alteration and diagenesis.

?Thie would mesn that although enrichment in organic phases ie entirely kely via exchange with humic acid, Th undergoes transfer to clay material during sedimentation and alteration. Hasean (1973) concurs with Seeley (1964) thet uranium my be much more stable in organic and Phosphate constituents.

?The Th/K ratio in Silurian Focene clays sesociated with

petroleun bearing substrat

was well correlated vith Tilite erystal-

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unity which in tum is associated with deep burial diagenesis (Hassan and Hossin, 1975). Thus 4% ie tempting to speculate upon the Th/K ratio in the Islote or other off-shore areas in Puerto Rico.

Such speculation based upon Appendix A of this report Ae very i1l-advised. The samples for which gemma epectra were ?measured were entirely composed of surface soils. ?The potasstun {in these sotts would have been subject to intense leaching due to

?their location in a subtropical zone. A high degree of leaching of K compared with Th would be expected and the net result could be artificially high values of the T/X ratio when compared with deep-

?urled sedimentary deposits.

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nental? crust; @ new table". Geochin. Cosmochim. Acta 28, 1273,

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APPENDIX AY

?Hppendix K consists partially oF mumerical print-out of records stored

on the PDP-10 computer at the Mayaguez A. & M. University computer cente:

110 blocks in 24 files, Dise. B (DSKB), weer designation: /250351, 2503167

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?Appendix A shows the actual munerical values of counte per

channel for the different spectra taken. The channel mmbers in the

column on the extrene left have the mumber of counts specified by the

first mumerical value to the right of the channel minber. Subsequent

channel munbers and the mumber of counts in each are read horizontally

from left to right, For example in spectrum ABB:003 (ng. A-1), channel musber 104 registered 801 counte, channel number 105 registered 772 counta, ?channel number 106 registered 730 counts ete.

Background measurements were made frequently and counting times were of the order of 2000 minutes to develop mjor gama peaks. ?These lone counting times reflect the relatively low efficiency of Ge-14 as a detector of gama emissions. ?Table AA-I gives basic data on each spectrum taken and shows on which page the spectrun is located.

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Appendix B

A Glossary of Symbols for Chemical Elenents

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Symbols for chemical elements mentioned or prominent in this report are

Listed in alphsbetical order with the technical nane of the element.

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